Work package 2 Task 2.2 Workshop

- PRESENTATION BY
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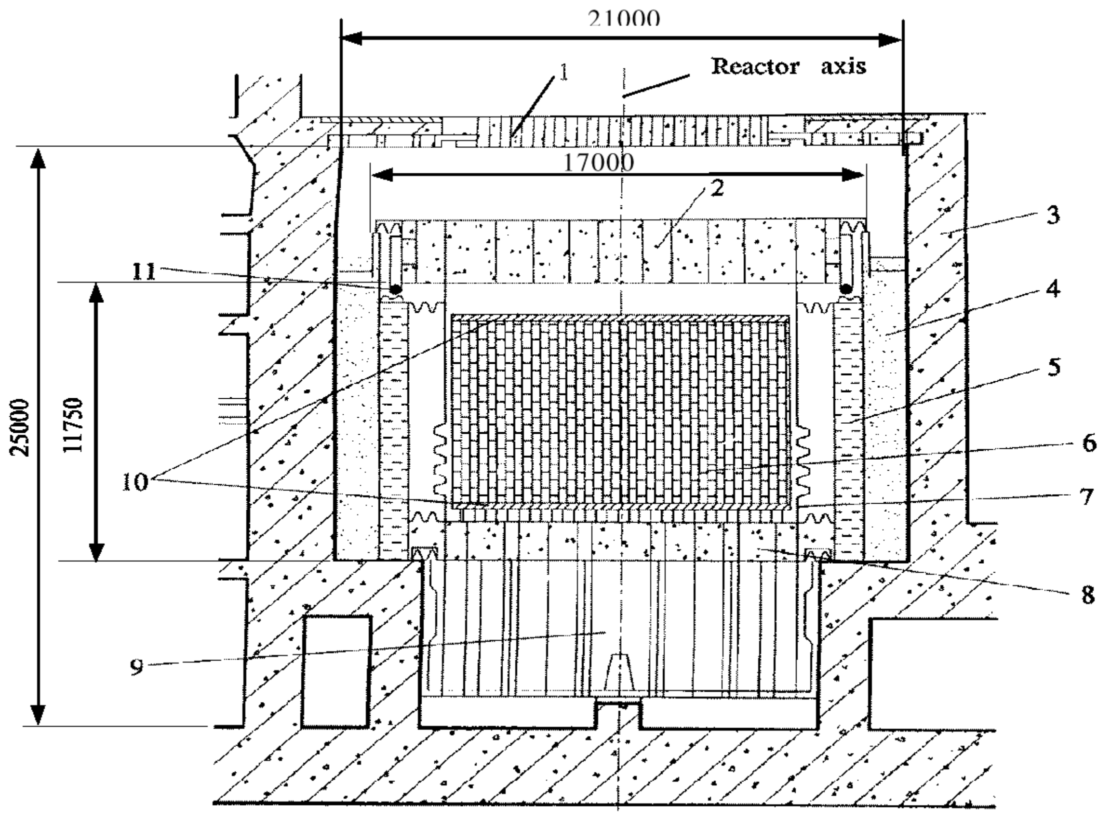
- TITLE
  - *RBMK (Ignalina)*

- Date 14 July 2009 at Doosan Babcock, Gateshead

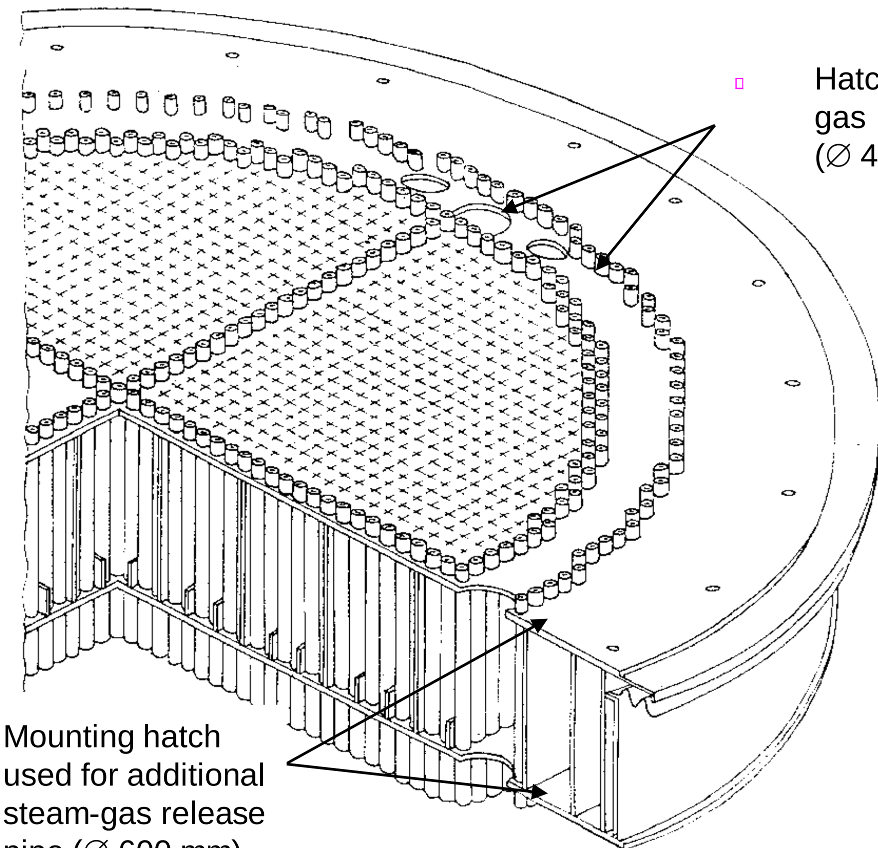
Relevant Background Data



RBMK-1500 reactor

1 – plate floor, 2 – top metal structure with serpentinite filling, 3 – concrete vault, 4 – mounting space with sand filling, 5 – lateral biological shield (annular water tank), 6 – graphite stack, 7 – reactor case, 8 – bottom metal structure with filling, 9 – reactor support structure, 10 – support (bottom) and shield (top) steel plates, 11 – roller supports

Relevant Background Data

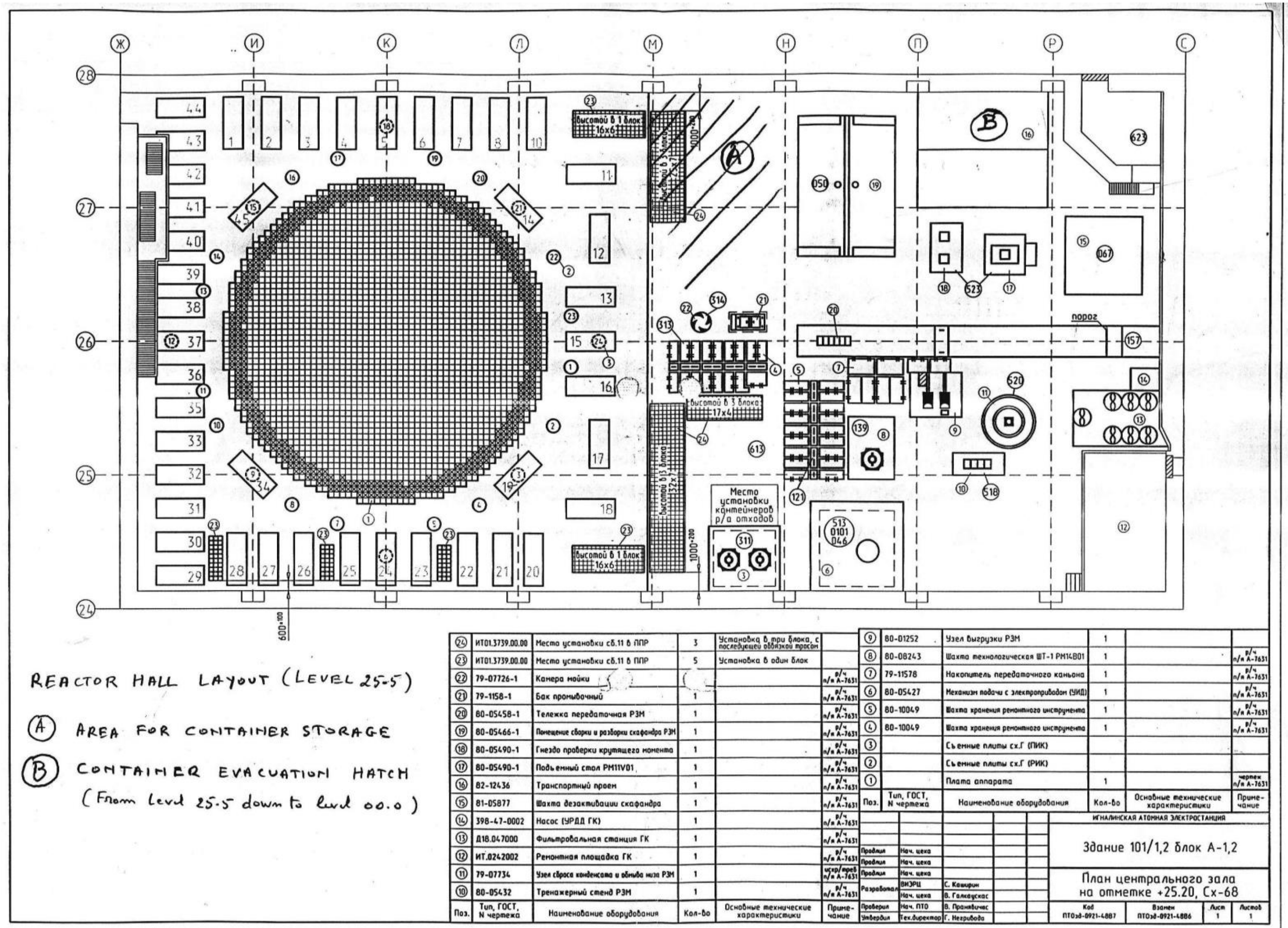


- Hatches for steam-gas release pipe (∅ 400 mm)
- Mounting hatch used for additional steam-gas release pipe (∅ 600 mm)

RBMK-1500 reactor
Top metal structure

- Overall dimensions of structure, mm Ø 17650x3000.
- Mass of metal structure 593405 kg.
- Mass of filling, not less, 1005000 kg.

Relevant Background Data



Plan of Reactor Hall

Relevant Background Data

- Total amount of channels in reactor core is 2070, including:
- · fuel 1661;
- · CPS (reactor control and protection system) 235;
- · reflector cooling 156;
- · temperature 17;
- · gas sampling 1.
- Core dimensions: Ø 11800 mm, height - 7000 mm. Core lattice is square with pitch 250 mm.
- 17 temperature channels and gas sampling channel are located outside the lattice.

Relevant Background Data

- Brief reference to study work already undertaken
  - Review reports, Data Pack, Route Map Step 2
- Focus on what this workshop needs to know (if no info, say so!)
  - Contributory impacts
    - *Comment on issues on Route Map Step 2 see – next slide*
  - Major issues
    - *Indicate state of development for i-graphite retrieval*
    - *What is needed to advance to a commercial solution*

Comment on Contributory Impacts

- Physical and Chemical Properties of graphite
  - Efficiency of the graphite stack ("Standards for Calculation of Strength of Graphite Assemblies and Graphite-uranium Reactor Parts" named НГР-01-85 in Russian, Ref. No. К-3624, refer) is determined by the following criteria:
    - *· Critical graphite damage level (neutron critical fluence, Fcr), under which a fast degradation of graphite properties happens, leading to graphite, as structural material, loss of bearing ability;*
    - *· Critical change of graphite units (bricks) geometry, under which the reactor core efficiency disrupts in the whole – exhaustion of technological radial expansion gap in the system: graphite units (bricks) – graphite rings*(sleeve) – fuel channel (jamming of FC in the graphite stack and possible destruction of graphite components when FC is being extracted);
    - · Graphite blocks integrity failure (intense cracking), under which abruptly disrupts the blocks' ability to function as the core area structure components and which requires a special attention during reactor dismantling.

Comment on Contributory Impacts

- Physical and Chemical Properties of graphite
  - In accordance with the special "Regulations for the In-Service Inspection of Fuel Channels, CPS Channels and Graphite Stack of the RBMK-1500 Reactor" there is a periodical monitoring of the graphite stack provided, which includes a visual graphite check with a television camera after FC is extracted in order to detect mechanical damages (cracks, chips, holes and etc.).
  - The criterion of neutron irradiation critical fluence, neutron fluence, is used as radiation resistance criterion for graphite items (graphite units (bricks), solid contact rings (sleeves) and etc.).
  - When it is reached, linear dimensions of the graphite items after shrinkage stage reach reference value.
  - When this neutron fluence is reached, graphite is in the "secondary swelling" stage, which is characterized by intense cracking, rapid deterioration of all graphite physical and mechanical properties (strength decrease, heat conduction and etc.). This leads to its efficiency loss.

Comment on Contributory Impacts

- Physical and Chemical Properties of graphite
  - According to the "Work programme on arrangement of reference graphite bushings in temperature channels of enterprise Unit 1, A-1513 (INPP) and further control of graphite stack condition" the reference graphite bushings are installed in six temperature channels, cells 06,5-24,5; 22,5-24,5; 24,5-30,5; 26,5-24,5; 34,5-24,5; 42,5-24,5, as samples-evidences under reactor dismantling (Protocol ПНР-53 dated 1984.01.27).

Comment on Contributory Impacts

- Physical and Chemical Properties of graphite
  - In order to carry out postreactor research and efficiency forecasting duringplanned maintenance of 1992, there were graphite bushings extracted from the cell 06,5-24,5.
  - The reference graphite bushings have been cut out parallel and perpendicular to the unit axis (two cutting directions considering texture) from the ready-made graphite blocks of standard ГР-280 (in Russian) brand reactor graphite, which are installed in the INPP Unit 1 reactor core.
  - Metrological data analysis showed that virtually all bushings have been irradiated under temperature of (650÷700)°C to neutron fluence (3,1÷3,5)·1022 n/cm2.
  - Results showed that the graphite compression strength has increased by (63÷95)%, and coefficient of elasticity – by (51÷95)%.

Comment on Contributory Impacts

- Potential methods of removal
- Graphite Moderated Gas Cooled Reactors – RBMK Operational Maintenance and Repair Experience
- Due to the basic design differences from LWR, most of the today industrial decommissioning feed back is expected to come from the already performed and on-going graphite moderated and gas cooled decommissioning projects, at least for the preliminary dismantling phase (graphite removal and handling of pre-cut of components), as those reactors exhibit similar technological features with RBMKs.
  - Fort St Vrain (USA),
  - Windscale AGR and Magnox Reactors in UK,
  - Japan,
  - Italy,
  - HTR and AVR (Germany)

Comment on Contributory Impacts

- Potential methods of removal
- Final cut operations (size reduction) can be performed under water, for example in some of the emptied spent fuel pools, with already proven tools.
- Dismantling, technique and tool inputs are also expected to come from the RBMK Russian Designer, who has now tackled up the RBMKs dismantling studies.

Comment on Contributory Impacts

- Potential methods of removal
- However, as shown hereafter, the already accumulated experience during operational maintenance and repair works is of primary importance in preparing RBMK dismantling sequences.
- The following table compares the main technological features of INPP RBMKs and of the Graphite Moderated Gas Cooled Reactor.

Comparison of RBMKs and Graphite Moderated Gas Cooled Reactors Technological Features

Feature	Ignalina RBMKs	Typical Gas Cooled Reactor
Long channel components	Fuel and cooling water channels, control rods etc, below standpipes	Details vary, but basically channels for fuel, cooling gas and control rods below standpipes
Large area at charge face	Access to channels is through removable shield blocks at vault floor	Access to channels is through removable shield blocks at charge face
Above core structures	Top cover, steam/water Pipework bundles	Details vary, but basically, guide tubes, neutron shield, and pipe bundles
Graphite stack	Graphite moderator and reflector comprising several thousand blocks	Graphite moderator and reflector comprising several thousand blocks
Core support structure	Core support structure for graphite stack and other components	Core support structure for graphite stack and other components
Cylindrical structures	Diaphragm, water cylinder and sand cylinder around graphite	Core restraint structure around graphite. Not a continuous structure, but still requiring 360 degree access
Pressure Vessel	Doesn't exists, pressure is contained in the channels, the major key design difference, may or may not affect dismantling, according to option chosen etc.	Spherical and cylindrical pressure vessels, either steel or prestressed concrete
Concrete structures	Reactor is surrounded by the concrete vault	Reactor is surrounded by the concrete bioshield, either separately in the case of steel vessels, or integrally for prestressed concrete vessels
Penetrations	Large openings through the concrete vault for steam and water pipes, standpipes for fuel, control, and instrumentation	Penetrations through the bioshield for gas cooling, inlet and outlet, standpipes for fuel, control instrumentation

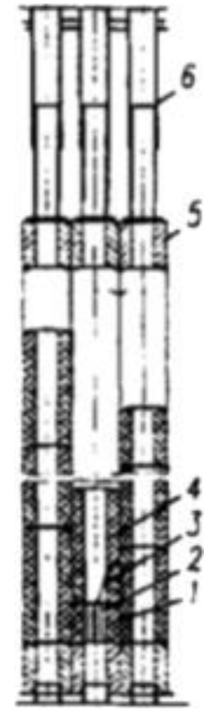
Comment on Contributory Impacts

- Potential methods of removal
- Leningrad nuclear power plant were tasked with solving the following problem:
- - to develop a technology that would make it possible to extract from the reactor an entire graphite column for shipment to IRTM of the Russian Science Center "Kurchatov Institute" and
- - to restore the graphite masonry of the reactor in the third power-generating unit, in which cell 52-16 operated without a graphite column 'after the liquidation of the consequences of a loss of seal in the access channel in March 1992.

Comment on Contributory Impacts

Leningrad NPP

- In 1992, during the liquidation of the consequences of the loss of seal in the access channel, the top steel plates of cells 52-16, 52-17, and 53-16 of assembly 07 were lifted into the extreme top position and clamped to the pipes in the top sections.
- All 14 graphite blocks were removed from cell 52-16 by grinding.
- In order to remove the fragments of graphite and fuel assemblies from the gaps, the adjoining columns were alternately moved, block by block, into the empty cell 52-16.
- Next, these columns were put back into their intended position. However, one 200 mm high block (position 2) from cell 53-16 and one 600 mm high block from cell 52-17 (position 4) where damaged when the blocks were moved.
- The first block had several cracks (position 1) over its entire height, and the second block had a 250 mm long U-shaped crack (position 3) at the bottom. The damaged blocks were left in cell 52-16.
- After they were removed, access channels were installed in all of the enumerated ceils. Fuel was loaded into the channels of cells 52-17 and 53-16 with incomplete graphite columns, and an additional absorber was placed in the channel of cell 52-16 with two damaged graphite blocks. The reactor continued to operate in this state without any limitations on the power.



Initial state of cells 53-16, 52-16, and 52-17.

Leningrad NPP

- In 1997, specialists at the Leningrad nuclear power plant developed a technological process for complete restoration of the graphite masonry of cells 52-16, 52-17, and 53-16, and they devised a system of mechanisms and hardware.
- The graphite masonry in the damaged cells was restored during the planned major overhaul.

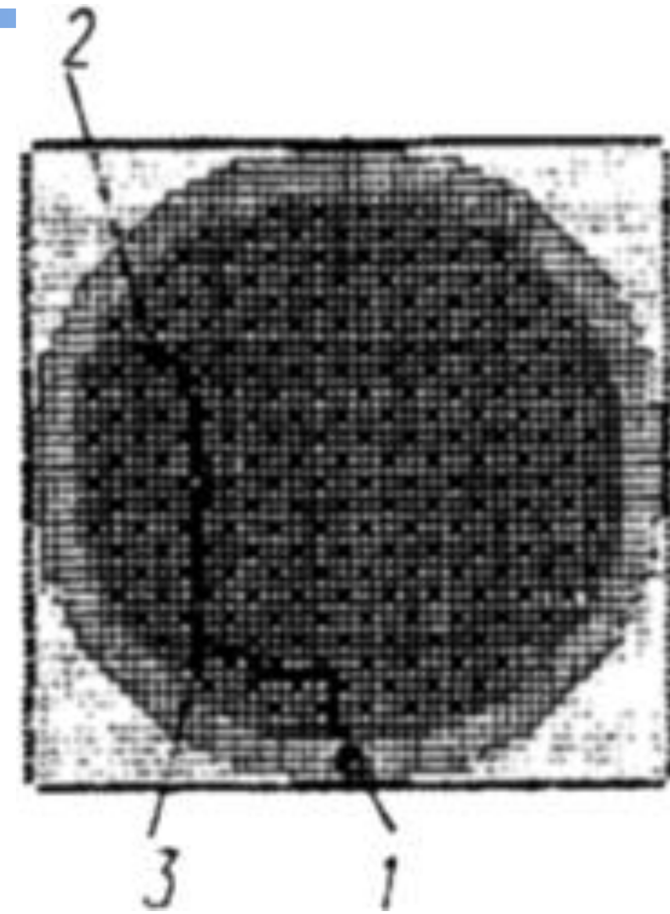
Comment on Contributory Impacts

Leningrad NPP

- A passage for the steam-gas exhaust system was installed at the top of the radiation shielding of the reactor (scheme E) in order to restore the graphite masonry during the planned maintenance work. Its location is shown in , position 1.
- The passage has a minimum diameter of 570 mm in the bottom sheet of the scheme E. Entire graphite blocks (250 • 250 x 600) and columns of blocks in an assembly (15 blocks) where transported through the passage into and out of the reactor core.
- However, the damaged cells (position 2) are located at a substantial distance fi'om the passage.
- Since during this period the access channels were replaced in the third power-generating unit and restoration of the graphite masonry requires removing the channels from the cells on which work is being performed, a decision was made to restore the masonry by moving the graphite blocks and the columns of blocks along the route devised (position 3).
- The algorithm for the solution adopted consists in the following.

Comment on Contributory Impacts

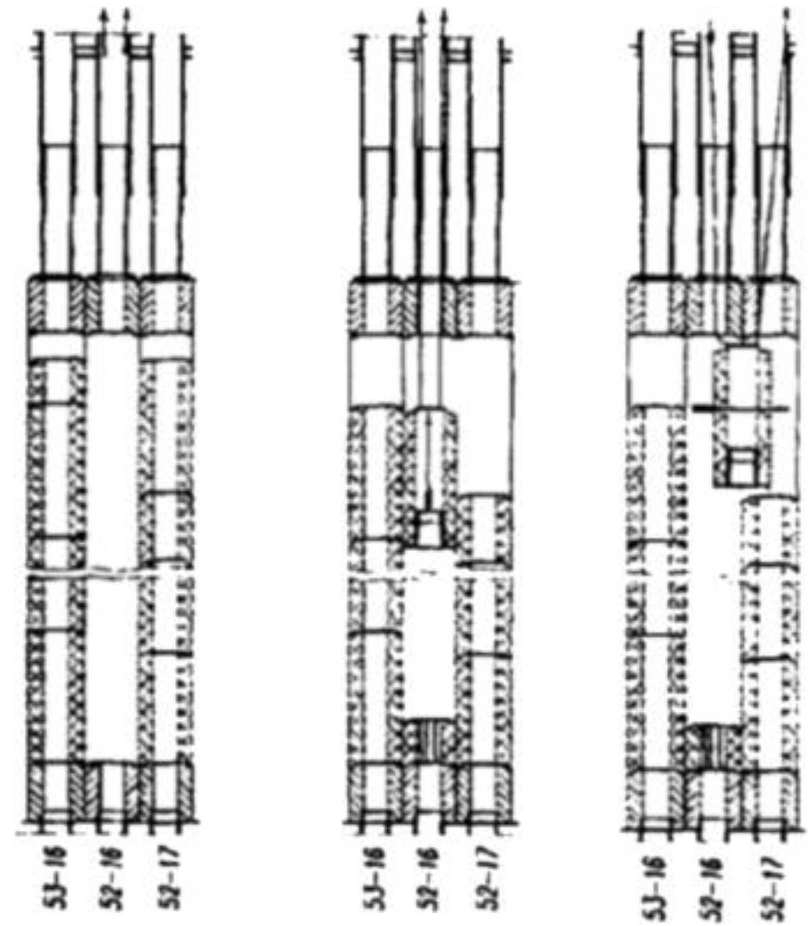
- Leningrad NPP
- The algorithm for the solution adopted consists in the following:
- The 600 mm high damaged block from cell 52-16 is put back into cell 52-17, into the cell from which it was lowered into cell 52-16.
- The 200 mm high block from cell 52-16 is put back into cell 53-16, into the cell from which it was moved into cell 52-16.
- Thus, cell 52-16 will be completely freed of graphite blocks (Fig. 3).
- Then, entire graphite columns are moved from cell to cell along the route devised (see Fig. 2, position 3), taking into account the fact that in certain ceils the access channels had already been replaced.
- The first column was moved from cell 51-16 into the empty cell 52-16. The route had an end point: the passage for the vapour-gas exhaust.



- Plateau of the reactor

Comment on Contributory Impacts

- Leningrad NPP
- Cell 52-16, freed of graphite blocks
- Lifting of a 600 mm high block
- Moving the 600 mm high block into cell 52-17.



Comment on Contributory Impacts

- Leningrad NPP
- Three types of toilet grips, differing by the height of the housing, were developed for moving the graphite blocks and entire columns.
- A special key with a built-in KTP- 155 TV camera was developed in order to lower a grip to the required marker and to control the collet grip.

Comment on Contributory Impacts

- Leningrad NPP
- While it was being moved, the 200 mm high block broke up because of cracks present in it. It had to be broken into small pieces and removed from the core through the bottom channel. Subsequently, it was restored into cell 53-16 in graphite segments.

Comment on Contributory Impacts

- Leningrad NPP
- In the course of the work, a decision was made to extract from the core columns of entire graphite blocks of cell 12-36 in order to investigate the state of the graphite.
- For this, the following operations were performed after the columns were moved from cell 13-36 into cell 14-36:
  - The graphite rods where extracted, using a special vacuum suction device, from the opening in the columns of cells 07-37 and 06-37 in the reflection zone, and the columns of blocks in cells 06-37 and 07-37 where extracted, using the collet grip, through the vapour-gas exhaust passage.
  - The column of cell 10-37 was moved into cell 07-37 and extracted.
  - Moving successively the column of blocks from cell in cell, the columns of cells 11-36 and 12-36 were also extracted from the core.
- In total of two columns where extracted from the reflection zones and four columns were extracted from the core.

Comment on Contributory Impacts

- Leningrad NPP
- Columns of new graphite blocks were placed in cells 13-36 and 12-36 by successively moving the columns from cell to cell. The columns of graphite blocks from cells 11-36, 10-36, 10-37, 07-37, and 06-37 were moved into their proper positions.
- The columns where extracted and positioned through the steam-gas exhaust passage. The column of graphite blocks from cell 12-36 was shipped to IRTM of the Russian Science Center "Kurchatov Institute" for study.

Comment on Contributory Impacts

- Leningrad NPP
- **The external gamma radiation made the main contribution to the dose load to the personnel.**
- **The gamma-ray dose rate at the work stations did not exceed the average value tbr the reactor plateau and was equal to 2 ~R/sec.**
- **The gamma-ray dose rate next to the extracted graphite column of cell 12-36 was 150-300 ~R/sec, on the average, over the entire height of the column.**
- **The maximum value 30 p.R/sec was observed on the graphite blocks 10 m from the top.**
- **The indefinite surface contamination of a graphite column with ~ and 13 emitting nuclides was -70 and 2000 particles/(cth2.min), respectively.**
- **A radionuclide analysis of smears taken from surface of a graphite column showed that 60% of the surface contamination was due to 60Co and 40% due to 134'137Cs and 144Ce.**
- **The collective equivalent dose for the entire period of work from September 2 to December 2, 1997 reached 19.88 man-rem.**
- **The maximum individual dose was -1.69 rem, and the average dose was -1. 1 rem.**
- **The allowed dose was not exceeded during the conduct of the work.**

Comment on Contributory Impacts

- Leningrad NPP
- For the first time in the history of the operation of RBMK reactors, an entire column of graphite blocks was removed from the core.
- Investigation of these blocks will provide answers for many questions concerning the behaviour of the graphite masonry during operation.
- These investigations are of great importance for the safety and reliability of power-generating units and for increasing their service life.
- The technology, developed and tested in practice, for restoration and replacement of the graphite masonry of an RBMK reactor shows that the masonry can be repaired without limiting the service life of the reactor.

Comment on Contributory Impacts

- Potential methods of removal

- Any current options being considered

- IGNALINA NPP. First Option: Dismantling of the Channels and Removal of the Graphite Columns with the Upper Shielding in Place (FDP for INPP)
- This sequence enables:
  - *the dismantling of the channels i.e. the most radioactive components of the reactor and*
  - *the removal of the graphite bricks*
  - *by implementation of already used techniques during maintenance and repair outages of RBMKs.*
  - *an important feature with respect to the operator's exposure lays into the fact that the upper shielding structure remains in place during the dismantling of those components.*

Comment on Contributory Impacts

- First Option
- The sequence involves the following steps:
- Removal of reactor channels. The existing technology, equipment and tools used during outages will be implemented.
- INPP records of events having led to reactor channel leakages are of high importance and will be analyzed in the very early stage of the reactor dismantling preparatory works in order to plan a cost effective dismantling activity;
- neutron and photon scanning technique will be implemented if necessary.
- Dismantling of central hall plate floor at the places of steam-gas release pipes entries into the top metal structure.
- Cutting of the steam-water pipes above the reactor in the zone of their entries (portable band saws).
- Cutting of the steam-gas release pipe works (external cutters).

Comment on Contributory Impacts

- First Option:
- **Removal of graphite stack columns (except reflector columns without channels).**
- **A procedure and technique elaborated and implemented at Leningrad NPP for the reconstruction of the graphite stack after fuel channel incident, can be used.**
- **The main idea consists of sequential shifts of the graphite columns from one location of the graphite stack to another and their final removal through the steam-gas release hatches in the top metal structure.**
- **At first, shield steel plates of neighbour cells are lifted and fixed in upper position by special equipment.**
- **A collet clutch is inserted into the central hole of a graphite column via the empty channel path by two steel ropes.**
- **The appropriate position of the clutch is controlled by TV camera.**
- **The clutch is attached to the graphite column and is subsequently lifted together with the graphite column using one rope to a a height sufficient for moving.**
- **After that the other rope is shifted to the neighbouring stack position by means of a special hook.**
- **When pulling this rope and releasing the first one, the column is moving to the neighbouring cell.**
- **The procedure starts with the removal of the column right underneath the steam-gas release hatch.**
- **By utilizing all of these hatches the procedure can be speeded up significantly.**
- **The inserted graphite rods in the lateral reflector columns are removed by a special vacuum plug.**

Comment on Contributory Impacts

- First Option:
- **Complete dismantling of the central hall plate floor.**
- **Cutting of the remaining steam-water pipes and reactor channels paths above the upper biological shield (portable band saw, external cutters).**
- **Removal of the top metal structure filling (the technology used during modernization of steam-gas mixture release system can be implemented for removal of the serpentinite filling – “vacuum cleaner”).**
- **Dismantling of the top metal structure and removal of remaining graphite columns.**

Comment on Contributory Impacts

- First Option:
- The removal of the core graphite stack without preceding dismantling of top metal structure reduces the irradiation exposure of the personnel.
- However, this technology leads to increase the duration of work. To smoothen this disadvantage, the parallel works through some hatches can be implemented.
- A second option, using remotely operated tools for the graphite handling, is proposed hereafter.

Comment on Contributory Impacts

- First Option:
- *Graphite bricks handling* (see also option 2 hereafter)
- Containers to be loaded with graphite bricks can be installed in the central hall at level 25.20 m (see loading area A.
- During the preparatory works, it shall be verified that the floor of the proposed loading area can withstand a load of about 2 t/m2.
- The loaded containers are applied with their lid, lifted up with the central hall crane and evacuated via the containers evacuation hatch (Item B).

Comment on Contributory Impacts

- IGNALINA NPP. Second Option: Dismantling of the Channels with the Upper Shielding in Place – Removal of the Graphite Columns with a Remotely Operated Graphite Blocks Handling Grab
- The first step of this second option is similar to that of the first option (dismantling of the channels with the existing tools);
- The second step consists of the removal of part of the top shielding to gain access to the graphite stack.
- This is a critical stage of the reactor dismantling. A temporary shielding ("gamma gate") may be required to provide the needed protection.
- This temporary shielding ("gamma gate") will enable the introduction of the remotely operated graphite blocks handling grabs (Figure 9.18) for the lifting and handling of the graphite blocks.
- The aim is that the grab is inserted into the bore of the graphite bricks, i.e. in this case 114mm.
- By hydraulic or pneumatic means, the balls are expended to grip the bore.
- The graphite blocks are then lifted up by the central hall crane and transported to and remotely released into the evacuation containers .
- This type of graphite blocks grabs was widely used for the construction of graphite cores in the UK reactor and for the dismantling of Windscale AGR.
- Another type of grab used at Windscale AGR involved drilling holes into the top of the graphite block, where there is no bore (i.e. solid reflector block).
- The grab then creates a screw thread in the holes by tapping, and was found to be a very reliable method of lifting the blocks, better than the vacuum grab.

Comment on Contributory Impacts

- Equipment to be kept in service:
  - *Whatever the dismantling option will be, a number of existing operation, maintenance and repair equipment will have to be kept in operation till the dismantling of the reactor or installed for that purpose:*
  - *the fuel channels cutting and removal equipment;*
  - *the channel segmentation facility (FFLA), with improved throughput rates or, preferably, a new unit;*
  - *the central hall crane and hoisting devices.*

  - *Note:*
  - **The graphite set removal facility for Fuel Channels (FC) and Control and Protection System Channels (CPS C).**
    - *The graphite set removal facility is meant for removal of graphite sleeves from fuel channels сб.12 and working channels CPS сб.14, as well as for loading of removed graphite to the container for radioactive waste. The FC and CPS C, meant for utilization, are transported to the CH from the SPH by the RM transfer car.*
    - *The utilized FC or CPS C is taken out of the storage by the CH crane with carrying capacity 50/10t, is freed from the graphite set in the graphite set removal facility, then it is installed in Facility for fragmentation of long articles for fragmentation.*

Comment on Contributory Impacts

- <u>Preparatory Works</u>
  - *<u>It can be expected that the dismantling of INPP reactors will be the first large size industrial RBMK to be dismantled in the world.</u>*
  - *<u>The Russian and Ukrainian RBMKs will be dismantled in accordance with the different dismantling option, i.e. 50 years after the RFS.</u>*
- <u>The preparatory works to be conducted during the next 10-12 years will include:</u>
  - *<u>the development (design, manufacturing testing) of the remotely operated tools to carry out the dismantling operation sequence;</u>*
  - *<u>the improvement (or the replacement) of the channel segmentation facility;</u>*
  - *<u>the construction of a single mock-up of the reactor or mock-up of specific parts of the reactor. This (or these) mock-up(s) will enable to optimize the dismantling sequences and tools, as well as the training of the operators;</u>*
  - *<u>the selection of the tools and locations to carry out the final dismantling of the reactor pre-cut components;</u>*
  - *<u>the transportation ways of the dismantled equipment between the reactor hall and the final cut places, including the need for new openings and handling means (cranes, hoisting, devices).</u>*

Comment on Contributory Impacts

Graphite	tons	m³
Operational waste	55	46
Decommissioning waste: graphite bricks and sleeves for 2 units	3788	2945
Total	**3843**	**2991**

- On the basis of container internal dimensions of 2.8 m x 1.45 m and a height of 1.01 m, it is assumed that an average of 2.625 m^3 of graphite bricks could be placed inside one container (estimation basis: bricks of 0.25 m x 0.25 m x 0.6m only are considered, 50 being placed vertically on the bottom of the container and 20 being placed horizontally on top of the first layer).
- About 1140 containers would be required to pack the graphite waste. The external volume of these containers to be interim stored on the INPP site would represent some 7054m^3.

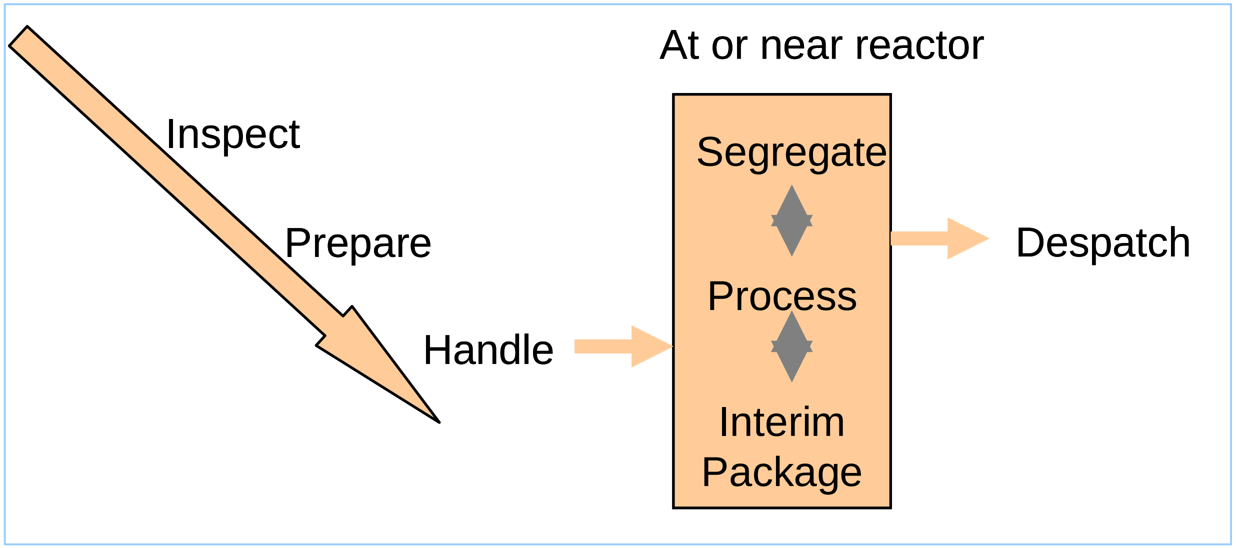
Comment on Contributory Impacts

- Other materials e.g. thermocouples, securing wires that might be encountered
  - Thermocouples will be removed before removal of the graphite
- Implications of reactor design on graphite retrieval
  - Especially any known complications not immediately obvious from the drawings: such information is not available

Decision Support Data

- Any other issues you may wish to raise that will facilitate of support the arrival at an i-graphite retrieval and segregation solution
- Any regulator comment on i-graphite management
  - Special regulations are not available.
- Any relevant cost data available e.g. budgets
  - Not available
- Any additional information arising from the information needs identified in Table 3 of the Data Pack
  - Note: no comments received to date

Flow Diagram



- Comment on this diagram with respect to
  - Magnox or
  - RBMK or
  - UNGG
- Update diagram is necessary
- Answer question: What impact has the information on the previous slides likely to have on this generic process?

Needs from Workshop

- With respect to the current state of knowledge on (Magnox, RBMK or UNGG)
  - Comment on current state of i-graphite retrieval (mode of dismantling) with respect to your reactor design (where are you at in the planning, safety case, implementation process):
  - Two preliminary options of reactor dismantling in FDP for Unit 1
  - Tendering for feasibility study on dismantling of the reactor
- What tools (in context of CARBOWASTE output) are still needed?
  - Comment on design/planning, modelling and implementation needs
  - Who needs the tools? Operators, regulators, contractors others?
  - Try and differentiate between the needs of these groups